



Recent Advances in Palynology

[Progrès récents en Palynologie]

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Paléobotanique
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**Chitinozoans of the lower Llanvirn Huy
and the middle Caradoc Sart-Bernard formations
(Middle to Upper Ordovician):
implications for the stratigraphy
of the Condroz Inlier (Belgium)**

**[Les chitinozoaires des formations de Huy, Llanvirnien inférieur,
et de Sart-Bernard, Caradocien moyen
(Ordovicien moyen et supérieur) :
implications stratigraphiques pour le Massif du Condroz (Belgique)]**

Jan VANMEIRHAEGHE¹

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Abstract: This paper reports on chitinozoans from the early Llanvirn (mid Darriwilian) Huy Formation found at three localities in the central Condroz Inlier: the Huy and Sart-Bernard railway sections and the Wépion borehole. In addition, it presents data on chitinozoans from the middle Caradoc (upper Sandbian to lower Katian) Sart-Bernard Formation, known from the eastern Sart-Bernard railway section and historically confused with the Huy Formation. We confirm the distinct palaeontological and lithological differences between the two formations, already noted by some authors. Our data, however, suggest that the Huy Formation is probably absent in the eastern Sart-Bernard section and demonstrate that the supposed stratigraphic hiatus between the Huy and Sart-Bernard formations is at least partly occupied by the soon-to-be-defined Chevreuils Formation. The chitinozoans indicate an early Abereiddian (early Llanvirn, mid Darriwilian) age for the Huy Formation and a Burrellian-Cheneyan age (middle Caradoc, late Sandbian to early Katian) for the Sart-Bernard Formation, thus narrowing the known stratigraphic range of these units. The chitinozoans of the Huy Formation have a northern Gondwana signature, whereas those of the Sart-Bernard Formation show clear Baltoscandian affinities.

Key Words: Biozonation; chitinozoans; Condroz Inlier; Llanvirn; Caradoc; Ordovician

Résumé : Les chitinozoaires du Llanvirnien inférieur (Darriwilien moyen) de la Formation de Huy ont été étudiés dans trois localités de la partie centrale de la Bande de Sambre-et-Meuse : les coupes de la voie de chemin de fer de Huy et de Sart-Bernard, ainsi que le sondage de Wépion. De plus, de nouvelles données sont ici présentées sur les chitinozoaires du Caradocien moyen (Sandbien supérieur à Katien inférieur) de la Formation de Sart-Bernard dans la coupe est de la voie de chemin de fer à Sart-Bernard, historiquement confondue avec la Formation de Huy. Nous confirmons l'existence de différences paléontologiques et lithologiques nettes entre les deux formations ainsi que cela a déjà été noté précédemment par certains auteurs. Nos résultats, cependant, suggèrent l'absence probable de la Formation de Huy dans la section est de Sart-Bernard et démontrent que l'hiatus stratigraphique supposé entre les Formations de Huy et de Sart-Bernard est occupé par au moins la Formation des Chevreuils qui sera définie bientôt. Les chitinozoaires indiquent un âge Abereiddien inférieur (Llanvirnien inférieur, Darriwilien moyen) pour la Formation de Huy et un âge Burrellien-Cheneyien (Caradocien moyen, Sandbien supérieur à Katien inférieur) pour la Formation de Sart-Bernard, précisant ainsi la position stratigraphique de ces unités. Les chitinozoaires de la Formation de Huy montrent une affinité nord-gondwanienne alors que ceux de la Formation de Sart-Bernard montrent des affinités baltoscandinaviennes claires.

Mots-Clefs : Biozonation ; chitinozoaires ; Bande du Condroz ; Llanvirnien ; Caradocien ; Ordovicien

1. General geological information

1.1. The Huy Formation

The Huy Formation was defined as the "Assise de Huy" by MALAISE (1909). We describe its lithology as slightly micaceous dark grey or black mudstone, with intercalated millimetric grey (fine-grade) siltstone beds, mostly with

diffuse limits, and a few fine-grade sandstone beds. Its base was observed in the Wépion borehole. It is a 5 cm thick pebble-supported conglomerate, disconformably overlying the Tremadocian Chevlipont Formation (*cf.* GRAULICH, 1961). The supposed transitional contact of the Huy Formation with the grey siltstones of the overlying Sart-Bernard

¹ Research Unit Palaeontology, Department of Geology and Pedology, Ghent University, Krijgslaan 281/S8, B-9000 Gent (Belgium)

Jan.Vanmeirhaeghe@UGent.be

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Formation was reported from the eastern Sart-Bernard railway section (km 73.110) by MAILLIEUX (1939). As we shall show no such contact is likely to be present.

The macrofauna of the Huy Formation consists of graptolites, trilobites, lingulid brachiopods, crinoids, molluscs, orthocone nautiloids and caryocaridids (arthropod zooplankton), along with trace fossils and coprolites. SERVAIS & MALETZ (1992) reviewed the graptolites of the Huy Formation and assigned them to the lower Aberdeiddian (lower Llanvirn) *D. artus* (= *D. bifidus*) Zone.

Estimates of the thickness of the Huy Formation range from more than 150 m (MICHOT, 1957) to more than 120 m in the Wépion borehole (GRAULICH, 1961). Disregarding the faults, which have an unknown displacement, the thickness of the Huy Formation in the western Sart-Bernard railway section is estimated by us at 100 m.

1.2. The Sart-Bernard Formation

The Sart-Bernard Formation, defined by MAILLIEUX (1939) as the "Assise de Sart-Bernard" is known only from the eastern portion of the Sart-Bernard railway section (east of km 73.110), which is also its type locality (MARTIN, 1969). It consists of grey micaceous siltstones, with a few grey micaceous sandstone beds and a nodule

horizon. The macrofauna comprises gastropods, bivalves, hyolites, brachiopods, trilobites and crustaceans (MAILLIEUX, 1939). It was originally dated as lower Llandeilian (MAILLIEUX, *ibid.*), but OWENS & SERVAIS (in press) mention a late Llanvirn (late Darriwilian) to Cheneyan (early Katian) age, with a preference for an early to middle Caradoc age interval (Sandbian to early Katian), on the basis of trilobite, graptolite and unpublished chitinozoan data (now published herein). We estimate the stratigraphic thickness of the Sart-Bernard Formation as between 80 and 115 m, but we saw neither the base nor the top of the formation.

1.3. The erroneously ascribed Huy Formation in the eastern Sart-Bernard railway section

MAILLIEUX (1939) reported the *D. bifidus* Zone from one fossil-bearing level (Naninne 2a), situated at km 73.078, a finding confirmed by BULMAN (1950). Consequently, MAILLIEUX (*ibid.*) considered the whole (poorly exposed) interval between km 73.0 and km 73.110 as the Huy Formation. This view was followed by later authors, because the lithology of the best exposed part of the sequence just west of km 73.110 resembles that of the Huy Formation. Our palaeontological results contradict the presence of the Huy Formation in the eastern Sart-Bernard railway section (see 5.2).

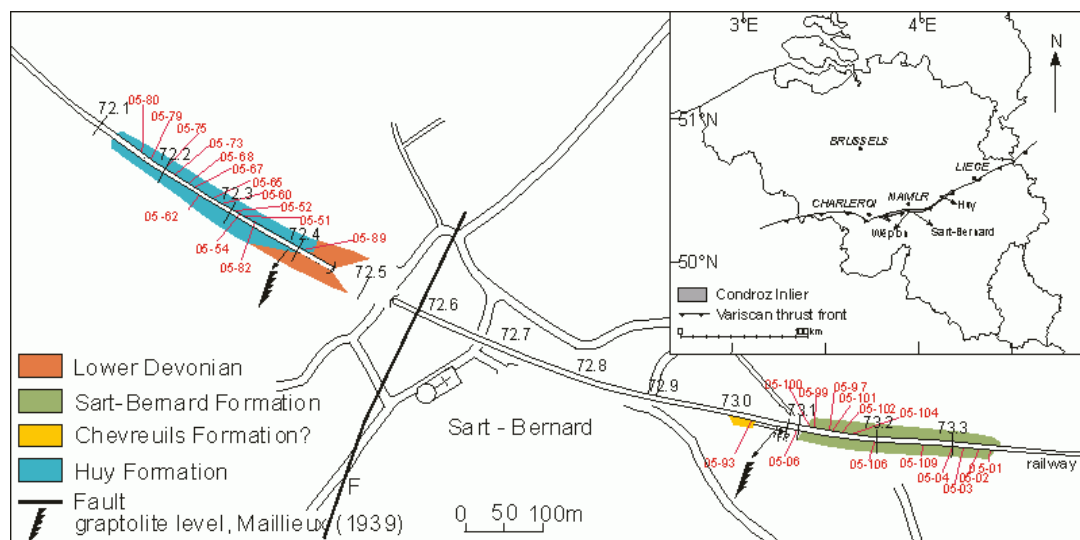


Figure 1: Location of the Condroz Inlier and the Sart-Bernard sections, with sample sites indicated. The map reflects a new geologic interpretation, in agreement with data in the text regarding chitinozoans and lithology.

1.4. The Huy and Sart-Bernard formations: the confusion

In his summary of the Ordovician and Silurian rocks of Belgium, MICHOT (1954) recognized the black shales of the Huy and Sart-Bernard sections as the "Assise de Huy" (MICHOT, 1954, p. 47), but in his summarising stratigraphical chart he named it erroneously as the "Assise de Sart-Bernard" (MICHOT, 1954, p.

75). Unfortunately, MAILLIEUX (1939) had already assigned this name to the grey siltstones of the eastern Sart-Bernard railway section. MICHOT (1954) incorporated this unit into his "Assise de Vitruval-Bruyère", but his assignment was not accepted by other authors.

MARTIN (1969) recognized a distinction between the "Assise de Huy" and the "Assise de Sart-Bernard", but erroneously referred the

whole eastern Sart-Bernard railway section to the "Assise de Sart-Bernard" (MARTIN, 1969, p. 32). As BULMAN (1950) attributed the graptolite horizon at km 73.078 to the *D. bifidus* Zone, MARTIN (*ibid.*) attributed an early Llanvirn age to the "Assise de Sart-Bernard". As a consequence, VERNIERS *et alii* (2001) doubted whether the Huy and Sart-Bernard formations are synonyms in the central Condroz Inlier, and considered both of them to be of Abereiddian

(early Llanvirn, mid Darriwilian) age. OWENS & SERVAIS (in press) pointed out the difference in the ages of the Huy and Sart-Bernard formations, and inferred a stratigraphic gap, which includes at least the middle Llanvirn (middle Darriwilian), but probably also parts of the upper Llanvirn (upper Darriwilian). As we show below (2.2), our chitinozoan data confirm that the two formations differs in age, but do not indicate the existence of a large hiatus.

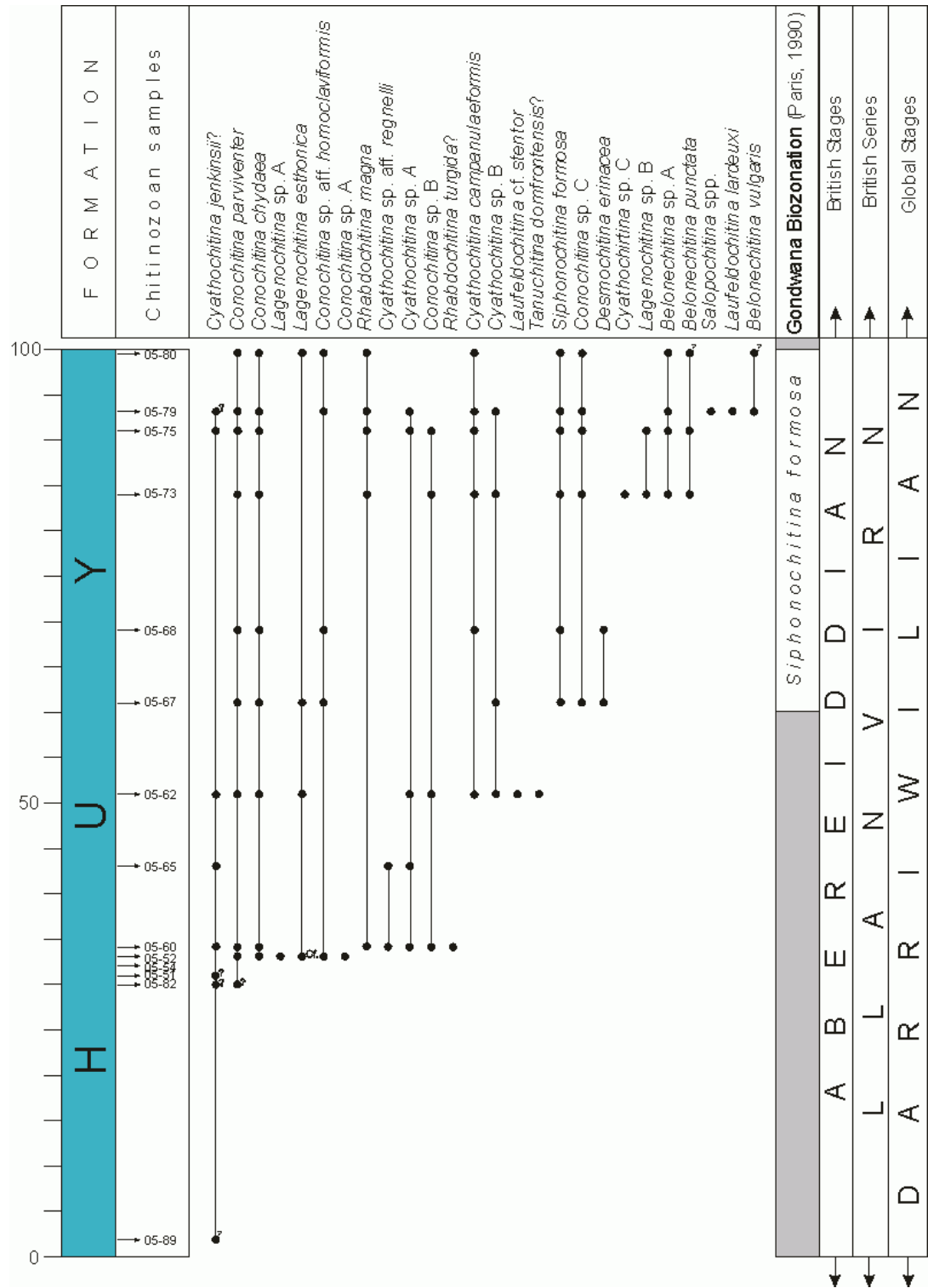


Figure 2: Chitinozoan distribution, biozonation and age assignment of the Huy Formation in the western Sart-Bernard section. The thickness and stratigraphic position of the samples are based on work in the field.

2. Chitinozoan biostratigraphy (Pl. 1)

2.1. Huy Formation (Fig. 2)

In the samples from the western Sart-Bernard railway section, the species of greatest value stratigraphically are *Cyathochitina jenkinsi*? (also found in the Huy and Wépion sections), *Cyathochitina* aff. *varennensis*,

Lagenochitina esthonica (also present in the Wépion and ?Huy sections), *Siphonochitina formosa* (also found in the Huy and Wépion sections), *Fungochitina vulgaris* (also ?Wépion), *Belonechitina punctata* (also ?Wépion) and *Laufeldochitina lardeuxi* (also Wépion). All but the two last-mentioned species were encountered by JENKINS (1967) in the Hope Shales (Shropshire, U.K., Avalonia), where

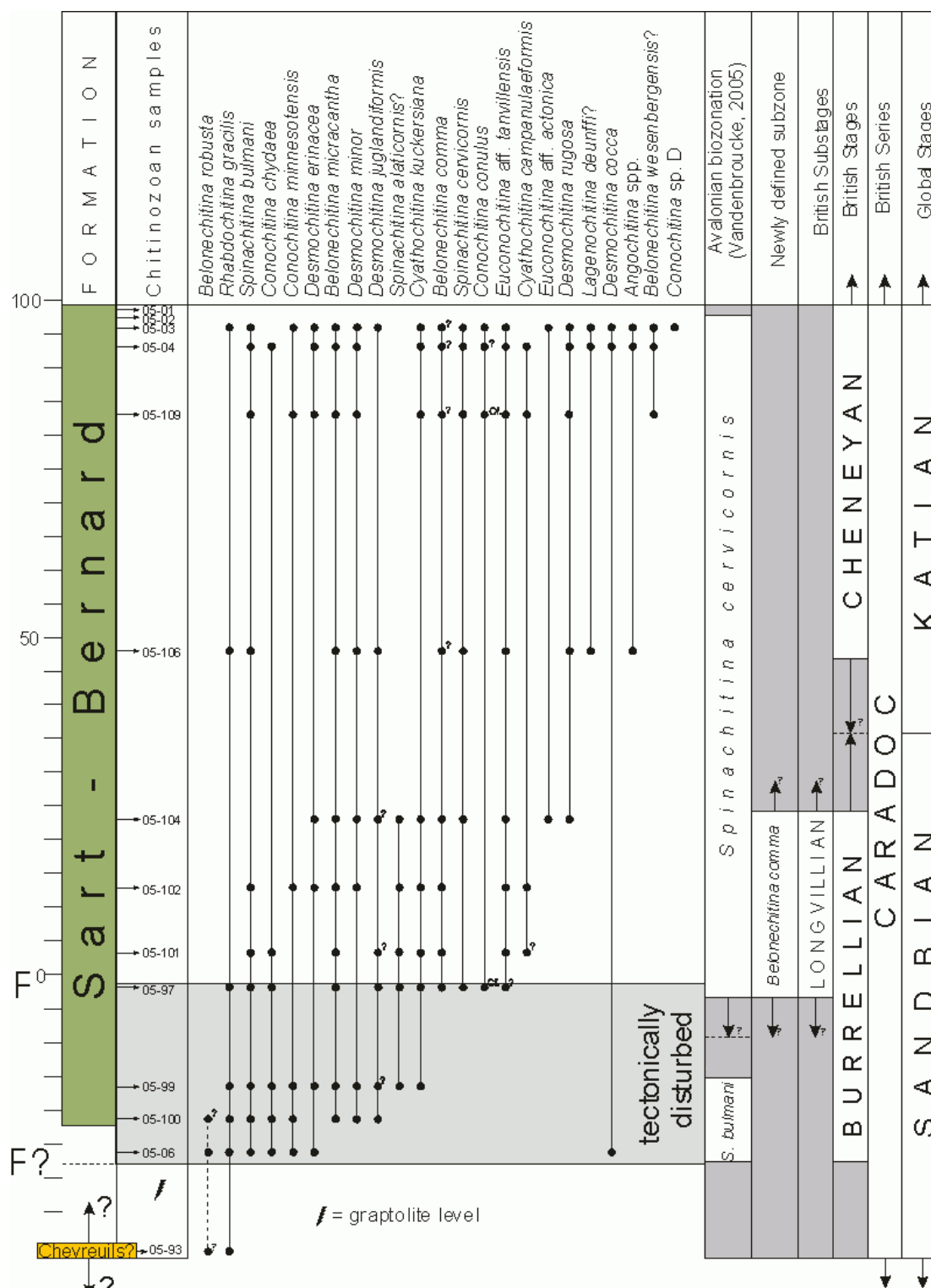


Figure 3: Chitinozoan distribution, biozonation and age assignment of the ?Chevreuls and Sart-Bernard formations in the eastern Sart-Bernard section. The indicated thickness and stratigraphic position of the samples are based on field work.

graptolites suggest an early Llanvirn age (STRACHAN, 1986). Our specimens of *C. jenkinsi*? are very similar to those in the Hope Shales assigned to *C. calix* by JENKINS (*ibid.*). We opt for a different identification, as various aspects of our specimens differ slightly from those of the Gondwanan index species *C. calix* (*sensu stricto*).

The chitinozoan fauna clearly has northern Gondwanan affinities (Fig. 4). With the exception of *C. jenkinsi*? and *C. parviverter*, all the species listed above are found in northern Gondwana in Llanvirn (middle to upper Darriwilian) strata (PARIS, 1981), and the ranges of some of them are restricted to that interval of time. In northern Gondwana, *Siphonochitina formosa* is the index species of the eponymous total-range zone (PARIS, 1990). The *S. formosa* Zone is correlated with the upper half of the *D. artus* graptolite Zone (WEBBY *et alii*, 2004).

An eye-catching species, *Salopochitina* sp. A (Plate 1.12), occurs in both the Huy and the western Sart-Bernard railway sections. This genus was formerly thought to be confined to the Wenlock-Ludlow interval, but may be used as guide fossil for a biozone situated in the *Siphonochitina formosa* Zone. PARIS *et alii* (*in press*) also did report the genus from the dark shales of the Sabova Formation of Turkey, which is attributed to the middle to late Darriwilian (Aberiddian). As is the case with our specimens, the *Salopochitina* specimens of PARIS *et alii* (*in press*) have a longer neck than the Silurian ones.

Our chitinozoan findings corroborate the presence of the lower Llanvirn (mid Darriwilian) *D. artus* graptolite Zone in the Huy Formation (SERVAIS & MALETZ, 1992), but *Cyathochitina protocalix* and *Cyathochitina calix*, in northern Gondwana known to occur in the lower part of this biozone, are not recognised in our samples.

2.2. Eastern Sart-Bernard section, west of km 73.110: partly Chevreuils Formation? (Fig. 1 & Fig. 3)

The assemblage of chitinozoans from the samples of what had been called the Huy Formation in the eastern Sart-Bernard railway section is different from that of the western section. The chitinozoans in sample JVM 05-93 (km 73.038, see Fig. 1) are poorly preserved, but *Rhabdochitina gracilis* and *Belonechitina robusta*? were recognised. The assemblage is completed by *Lagenochitina* spp. and *Siphonochitina* spp. The presence of *Siphonochitina* spp. and the absence of *Spinachitina* spp. and *Desmochitina* spp. suggest a pre-Burrellian (pre-late Sandbian) age. If so, the sample should be situated in the interval upper Aberiddian (above the *D. artus*

Zone) to Aurelucian, with a preference for the Aurelucian because of the presence of specimens resembling *B. robusta*.

In sample JVM 05-06 (km 73.097, see Fig. 1), *Spinachitina bulmani*, *Belonechitina robusta*, *Rhabdochitina magna*, *Desmochitina erinacea*, *Desmochitina cocca* and *Conochitina minnesotensis* occur. This assemblage is typical for the Burrellian (upper Sandbian – lower Katian) of the Onny Valley (*cf.* JENKINS, 1967; VANDENBROUCKE, 2005). An age older than Burrellian (late Sandbian) is excluded; in Baltoscandia as well, *B. robusta* first occurs in the Idavere strata (NÖLVAK & GRAHN, 1993), that are roughly correlative with the basal part of the Burrellian (WEBBY *et alii*, 2004).

Our chitinozoan data confirm a difference in the ages of the Huy and Sart-Bernard formations, but do not support the existence of a large hiatus between them. Indeed, the chitinozoan content of sample JVM 05-93, formerly considered to be situated in the upper part of the Huy Formation, is instead late Aberiddian to Aurelucian (late Darriwilian to early Sandbian), much younger than the early Llanvirn (mid Darriwilian). The lithology of this sample is strongly-burrowed, dark grey shale with small silt- and sandstone lenses and thus resembles the lithology of the soon-to-be-defined upper Llanvirn to lower Caradoc Chevreuils (upper Darriwilian to lower Sandbian) Formation (*cf.* VANMEIRHAEGHE, 2006a). Immediately below the base of the Sart-Bernard Formation as previously defined (at km 73.110), the Burrellian (upper Sandbian – lower Katian) is demonstrated in JVM 05-06. Therefore, the graptolite identifications of MAILLIEUX (1939) and BULMAN (1950) of the specimens collected at km 73.078, which they assigned to the lower Llanvirn (middle Darriwilian) *D. bifidus* Zone, need reconsideration, for in all probability the Huy Formation is absent in the eastern Sart-Bernard railway section.

These results imply the presence of a fault between JVM 05-93 (Chevreuils Formation?) and JVM 05-06 (Burrellian, upper Sandbian – lower Katian) (Fig. 1 & Fig. 3). Indeed, in the central Condroz Inlier, the Vitruval-Bruyère Formation (its base with thick sandstone beds) is inferred to occur between the Chevreuils and the Sart-Bernard formations, for it is correlated with the *Laufeldochitina stentor* Zone (~upper Llanvirn to Aurelucian, upper Darriwilian to lower Sandbian), of which it probably represents the uppermost element (Fig. 4). Because the upper boundary of Vitruval-Bruyère Formation is Onnian (late Streffordian, mid Katian) (VANMEIRHAEGHE, 2006b), the equivalent of the Sart-Bernard Formation must exist within the Vitruval-Bruyère Formation (Fig. 4). This



Plate 1: SEM microphotographs of chitinozoans of the Huy and Sart-Bernard Formations from the Sart-Bernard sections. All measurements in microns (L x Dp x Dc) or (L x Dp x Dc x Db), with L= total length; Dp= width of the chamber; Dc= width of the neck; Db= width at the base:

figure 1. *Lagenochitina esthonica*. 600 x 275 x 135. JVM 05-80; 05-1546. Huy Formation;

figure 2. *Lagenochitina esthonica*. 660 x 235 x 110. JVM 05-80; 05-1546. Huy Formation;

figure 3. *Cyathochitina jenkinsi*?. 250 x 160 x 90 x 130. JVM 05-75; 05-1542. Huy Formation;

figure 4. *Cyathochitina jenkinsi*?. 240 x 120 x 70 x 100. JVM 05-75; 05-1542. Huy Formation;

figure 5. *Lagenochitina* sp. A. 130 x 80 x 45. JVM 05-73; 05-1541. Huy Formation;

figure 6. *Fungochitina* aff. *tanvillensis*. 100 x 72 x 25. JVM 05-106; 05-1566. Sart-Bernard Formation;

- figure 7.** *Fungochitina vulgaris*. 100 x 60 x 40. JVM 05-79; 05-1544. Huy Formation;
figure 8. *Cyathochitina aff. varennensis*. 165 x 135 x 60. JVM 05-73; 05-1541. Huy Formation;
figure 9. *Conochitina parviverter*. 350 x 90 x 60. JVM 05-67; 05-1538. Huy Formation;
figure 10. *Conochitina parviverter*. 450 x 90 x 65. JVM 05-62; 05-1537. Huy Formation;
figure 11. *Desmochitina juglandiformis*. 1 specimen: 70 x 60. JVM 05-106. Sart-Bernard Formation;
figure 12. *Salopochitina* sp. A. 160 x 85 x 40. Length appendix: 160 µm. JVM 05-79; 05-1544. Huy Formation;
figure 13. *Spinachitina cervicornis*. 145 x 82 x 45. JVM 05-97; 05-1569. Sart-Bernard Formation;
figure 14. *Spinachitina bulmani*. 110 x 75 x 35. JVM 05-101; 05-1571. Sart-Bernard Formation;
figure 15. *Siphonochitina formosa*. Without siphon: 270 x 65 x 40 x 45. Siphon: 140 x 75 x 45. JVM 05-73; 05-1541. Huy Formation;
figure 16. *Siphonochitina formosa*. Without siphon: 310 x 60 x 32 x 42. Siphon: 120 x 60 x 40. JVM 05-73; 05-1541. Huy Formation;
figure 17. *Rhabdochitina magna*. 1100 x 115 x 90. JVM 05-73; 05-1541. Huy Formation;
figure 18. *Spinachitina cervicornis*. 145 x 80 x 40. JVM 05-97; 05-1569. Sart-Bernard Formation;
figure 19. *Cyathochitina* sp. C. 350 x 130 x 75 x 95. JVM 05-73; 05-1541. Huy Formation;
figure 20. *Belonechitina comma*. 230 x 60 x 30. JVM 05-104; 05-1572. Sart-Bernard Formation;
figure 21. *Belonechitina comma*. 230 x 60 x 30. JVM 05-104; 05-1572. Sart-Bernard Formation.

Global Stages ↑	British Series and Stages		Central Condros Inlier Formations		Avalonian Chitinozoan Biozonation	Chitinozoan affinity
KATIAN	C A R D O C	St	VITRIVAL-BRUYERE	SART-BERNARD	<i>cervicornis</i>	Baltoscandia
		Ch				
		Bu				
		Au				
SANDBIAN	C A R D O C	Au	CHEVREUILS		<i>stentor</i>	Avalonia?
		LI				
		Ab				
DARRIWILIAN	LLANVIRN	Ab	HUY		<i>formosa</i>	Gondwana

Figure 4: Stratigraphic position of the formations of the central Condros Inlier, as discussed in the text. On the right, Avalonian chitinozoan biozones found in the central Condros Inlier and their affinities with other palaeocontinents. The base of the Vitruval-Bruyère Formation is indicated as in the *L. stentor* Zone, but might be lower, given the range of the index species in Baltoscandia (NÖLVAK & GRAHN, 1993). However, the Chevreuils Formation in its type locality is situated in the upper Llanvirn to lower Caradoc interval. No specimens of *L. stentor* were seen in samples from that section. Possibly, this absence was caused by chitinozoan-endemism in Avalonia during late Llanvirn – early Caradoc times. Ab: Abereiddian; LI: Llandeiliian; Au: Aurelucian; Bu: Burrellian; Ch: Cheney; St: Streffordian.

conclusion is supported by the existence of a thick siltstone interval with a few sandstone interbeds in the type section of the Vitruval-Bruyère Formation.

2.3. Sart-Bernard Formation (Fig. 4)

Stratigraphically important species in the Sart-Bernard Formation are *Spinachitina bulmani*, *Spinachitina cervicornis*, *Desmochitina juglandiformis* and *Belonechitina comma*. The chitinozoan fauna is similar to that of British Avalonia (VANDENBROUCKE, 2005) and has a clear Baltoscandian signature.

VANDENBROUCKE'S (2005) data from British Avalonia suggest that the FAD of *S. bulmani* must be situated somewhere in the *D. foliaceus* graptolite Zone, which taken largely, corresponds to the Burrellian (upper Sandbian – lower Katian). In Avalonia, *S. cervicornis* ranges from the Cheney (lower Katian) to the Actonian (lower Streffordian, middle Katian), but its lowermost occurrence might be in the lower Burrellian (upper Sandbian), if the long-spined specimens attributed to *S. bulmani* are within the scope of the variations of *S. cervicornis* (VANDENBROUCKE, 2005). In any event, *S. cervicornis* co-occurs in some of our samples with *Desmochitina juglandiformis*, which in Baltoscandia has more or less the same range as *S. cervicornis*. In Baltoscandia, the *S. cervicornis* (total-range) Zone occupies the late Idavere-early Oandu time interval (NÖLVAK & GRAHN, 1993), and thus is of the age interval Burrellian (except for the basal part) to early Cheney or the late Sandbian – early Katian global Stages (WEBBY *et alii*, 2004; BERGSTRÖM *et alii*, 2005). *Belonechitina comma* is characteristic of the Jõhvi to Keila stages (NÖLVAK & GRAHN, 1993), that correlate with the middle to upper Burrellian (upper Sandbian – lower Katian).

In summary, the chitinozoans of the Sart-Bernard Formation correlate with the middle Burrellian to (lower) Cheney (upper Sandbian – lower Katian) and have a Baltoscandian signature (Fig. 4); the interval between and including JVM 05-97 and JVM 05-104 has a

middle to late Burrellian (~Longvillian, late Sandbian – early Katian) age (Fig. 3). From JVM 05-106 upward, it is quite probable that the strata are Cheneyan (early Katian). So chitinozoan data narrow the late Llanvirn (late Darriwilian) to Cheneyan (early Katian) age proposed by OWENS & SERVAIS (in press).

3. Conclusions

Chitinozoans from the Huy and Sart-Bernard formations, two units of the Lower Palaeozoic Condroz Inlier, Belgium, were collected and studied. The occurrence of the *Siphonochitina formosa* Zone in the Huy Formation is in agreement with the previously obtained graptolite data that assigned an early Llanvirn (mid Darriwilian) age to this formation. In the eastern Sart-Bernard section, the Huy Formation is absent in all probability, as the chitinozoans from two samples indicate a late Abereiddian to Aurelucian (late Darriwilian to early Sandbian) and a Burrellian (late Sandbian – early Katian) age. The western part of the eastern Sart-Bernard section might represent the late Darriwilian to early Sandbian Chevreuils Formation. The chitinozoans of the Sart-Bernard Formation are assigned to the *Spinachitina cervicornis* Zone and are shown to have a middle Burrellian to (early) Cheneyan (late Sandbian – early Katian) age, narrowing the previously proposed late Llanvirn (late Darriwilian) to Cheneyan (early Katian) range in age.

The chitinozoans show that Avalonia moved northward from Gondwana to Baltica during Ordovician times. The early Llanvirn (mid Darriwilian) chitinozoan assemblages of the Huy Formation are very similar to those of the same age in Gondwana, whereas those of the Burrellian-Cheneyan (late Sandbian – early Katian) have Baltoscandian affinities. Chitinozoans from the type locality of the Chevreuils Formation have no obvious similarities with contemporaneous assemblages on other palaeocontinents. We suggest that during late Darriwilian to early Sandbian times, the age of the Chevreuils Formation, Avalonia was at a latitude intermediate between that of Gondwana to the south and that of Baltica and Laurentia to the north. Furthermore, the lack of thermohaline circulation during the Early and Middle Ordovician and the peculiar position of the palaeoplates were conditions favourable to endemism (see references in ACHAB & PARIS, in press).

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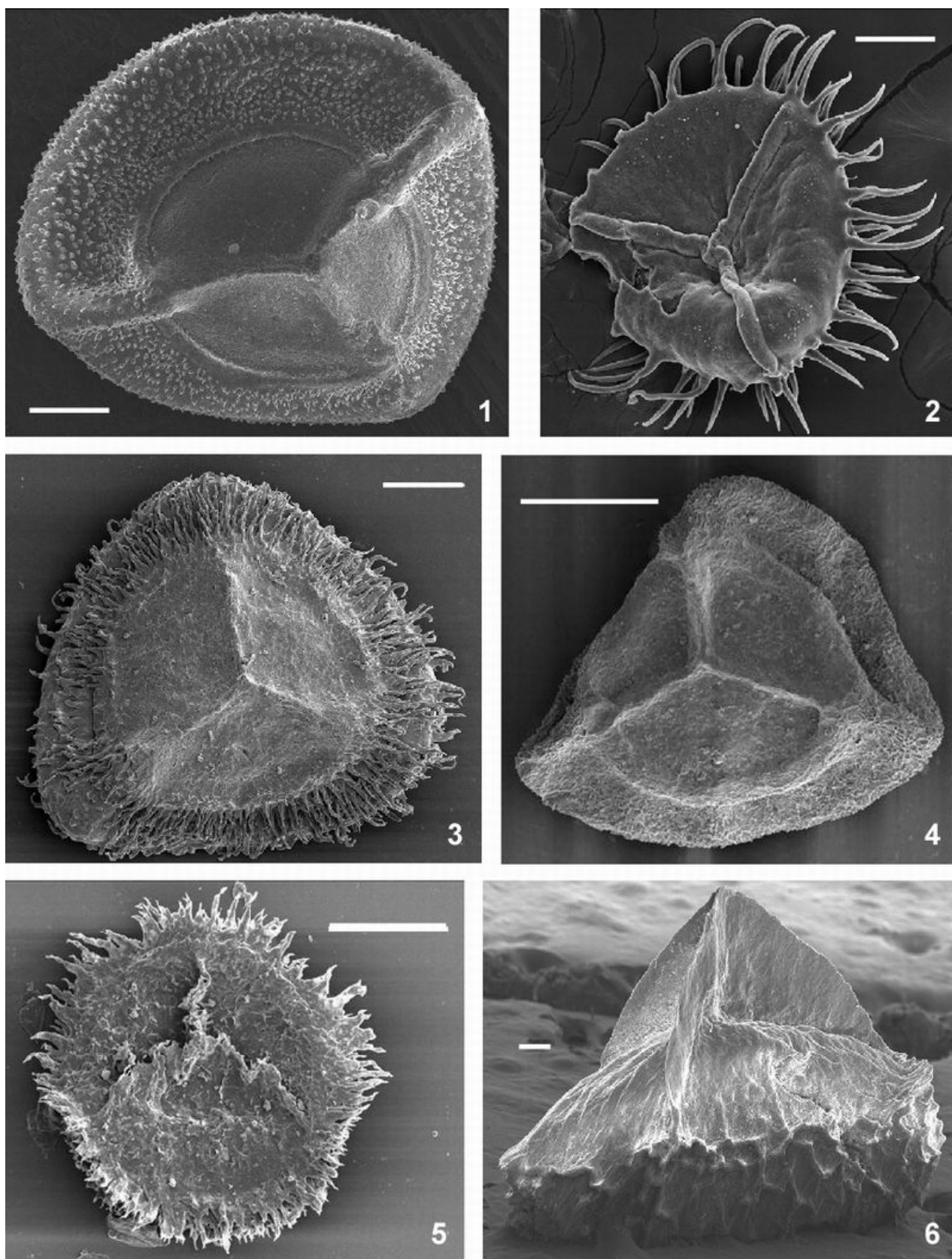


Plate 1: Some selected miospores from the Ronquières and A1-69 borehole sections (scale bars = 100 μm):
 figure 1. *Contagisporites optivus* (CHIBRIKOVA 1959) var. *optivus* OWENS 1971. Libyan specimen;
 figure 2. *Heliotriletes longispinosus* FUGLEWICZ et PREJBISZ 1981. Libyan specimen ;
 figure 3. *Biharisporites* sp. Belgian specimen;
 figure 4. *Contagisporites optivus* (CHIBRIKOVA 1959) var. *optivus* OWENS 1971. Belgian specimen;
 figure 5. *Corystisporites multispinosus* RICHARDSON 1965. Belgian specimen;
 figure 6. Undetermined specimen showing a large gula. Libyan specimen.